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Multimodal Instruction for Grade 9 Earth Science: Enhancing Mastery of Least-Learned Competencies at Cabancalan National High School

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Abstract:

This study investigated the effectiveness of multimodal instruction in improving Grade 9 students mastery of three least-learned competencies in Earth Science at Cabancalan National High School, Mandaue City, for SY 2024-2025. Grounded in Sweller Cognitive Load Theory, Kress Multimodal Theory, and Vygotsky Social Constructivism, the study employed a quantitative quasi-experimental one-group pretest-posttest design. Thirty-four students from Section Serenity (18 males, 16 females), identified as the lowest-performing section based on SMEA reports (2020-2024), served as respondents through purposive sampling. A validated 30-item multiple-choice instrument from the DepEd Learning Portal covering (1) explaining what happens when volcanoes erupt, (2) describing global climatic phenomena, and (3) inferring characteristics of stars based on the Sun, was used. Descriptive statistics and paired-samples t-test were utilized. Pretest revealed low mastery: Volcanoes M=3.74, SD=1.24, 55.88 percent Average Mastery; Climate M=4.34, SD=1.94; Stars/Sun M=3.23, SD=1.70, 32.35 percent Low Mastery, with zero Master. After 15 days of multimodal intervention integrating visual (infographics, Stellarium, videos), auditory (volcanic sounds, discussions), kinesthetic (DIY volcano, collage, model-making), and digital tools (Star Walk 2, VR), posttest scores increased significantly. Stars/Sun showed highest gain M=7.43, SD=1.40, 26.47 percent Master, 47.06 percent Closely Approximating Mastery, followed by Climate M=5.86 and Volcanoes M=5.63. Paired t-test confirmed significant differences for all: Volcanoes t(33)=4.83, p<.001, d=0.816; Climate t(33)=4.25, p<.001, d=0.719; Stars/Sun t(33)=10.31, p<.001, d=1.742, indicating large effects. Findings support that multimodal instruction effectively reduces cognitive load, enhances engagement, and promotes deeper conceptual understanding. Enhanced multimodal learning activities are proposed for broader adoption.

Keywords: multimodal instruction, Earth Science, least-learned competencies, cognitive load theory, quasi-experimental, Grade 9

Introduction:

In today's diverse educational landscape, learners demonstrate varied learning preferences that influence academic achievement, particularly in science. Earth Science remains challenging for many Grade 9 students due to complex processes, spatial-temporal concepts, and global-scale phenomena. At Cabancalan National High School, Mandaue City, SMEA reports for three consecutive school years (2020-2024) revealed consistent underperformance below the 75 percent passing threshold: 65.36 percent (2020-2021), 68.5 percent (2021-2022), 73.1 percent (2022-2023), and 72.8 percent (2023-2024). Factors cited include absenteeism, lack of interest, peer distractions, and pandemic-induced learning loss. This gap underscores inadequacy of traditional teacher-centered approaches relying on lectures, memorization, and standardized assessment (Sergeeva et al., 2020; Rabazas Romero et al., 2019), which limit active participation and higher-order thinking (Pliushch & Sorokun, 2022).

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The Philippine K-12 curriculum identifies least-learned competencies requiring targeted intervention. For Third Quarter Grade 9 Earth Science, these are: explaining volcanic eruptions, describing global climatic phenomena, and inferring stellar characteristics. These topics are inherently multimodal. Traditional verbal instruction fails to represent such multisensory realities. Multimodal instruction, defined as pedagogy integrating multiple semiotic modes - linguistic, visual, auditory, gestural, and spatial - to co-construct meaning (Kress, 2010; Kress & Bezemer, 2023), offers a promising alternative. Taylor and Leung (2019) argue modern literacy is inherently multimodal.

Research shows multimodal approaches improve retention, engagement, and critical thinking by catering to diverse intelligences (Ayimbila, 2020; Harun & Singh, 2024). This study addresses the gap on multimodal effectiveness in Philippine public junior high Earth Science. While international studies demonstrate benefits in vocabulary (Guo et al., 2024), biology (Akotuko & Azure, 2021), and dentistry (Gatt & Attard, 2023), limited local empirical data exists. Therefore, this study aimed to determine effectiveness on the three competencies at CNHS and craft enhanced activities. Findings hold significance for students, teachers, coordinators, principals, curriculum planners, and DepEd policymakers.

Literature Review:

Theoretical Foundation: This study is anchored on three theories. First, Sweller Cognitive Load Theory posits working memory is limited and learning is hindered by extraneous load. Effective instruction minimizes unnecessary demands and maximizes germane load using signaling, segmenting, and modality principles (Sweller, 2019; Paas & van Merrienboer, 2020). Castro-Alonso et al. (2021) emphasize multimedia and redundancy reduction. In Earth Science, presenting volcanic processes through synchronized narration, labeled diagrams, and segmented animation prevents overload versus lengthy lecture. Sozio et al. (2024) showed well-sequenced multimodal explanations improve deep comprehension.

Second, Kress Multimodal Theory contends meaning is made through multiple modes beyond language - image, gesture, sound, spatial arrangement (Kress & Bezemer, 2023). Science learning is inherently multimodal via graphs, symbols, models, digital media (Yeo & Nielsen, 2020). Unsworth et al. (2021) argue multimodal literacy scaffolding enhances engagement. Qian (2024) showed transformative effects in English vocabulary, while Shao (2022) demonstrated Mandarin pedagogy benefits. Harun and Singh (2024) found multimedia crucial for knowledge transfer. Prain and Tytler (2022) argued students learn science more effectively when they create, interpret, coordinate, and integrate multiple representations, a core principle adopted here using infographics, DIY volcano, Stellarium, and collaborative discussions.

Third, Vygotsky Social Constructivism views learning as socially mediated, active co-construction through interaction within Zone of Proximal Development (Taber, 2020). Rannikmae (2020) notes multimodal instruction unlocks peer interaction. When students collaborate to compute carbon footprints or observe constellations via apps, they co-construct understanding (Taber, 2020). Saleem et al. (2021) emphasize collaboration and authentic problem-solving. Shah (2019) positions teacher as facilitator in ZPD. Integration of CLT, Multimodal, and Social Constructivism suggests managing cognitive load through diverse representations while providing socially interactive opportunities leads to improved outcomes.

Empirical Evidence: Akotuko and Azure (2021) found SHS students taught biological classification via Multimodal Instructional Approach significantly outperformed traditional group. Batir and Akcay (2022) reported multimodal representations improved ability to communicate scientific understanding. Ayimbila and Pappoe (2022) observed improved retention in classification among 100 SHS students. Ortiz and Aliazas (2021) concluded multimodal strategies shifted Grade 4 pupils from developing to proficient in inquiry, supporting diverse learning styles.

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In Philippine context, DepEd Order No. 8, s. 2015 provides mastery descriptors: Mastered 96-100 percent, Closely Approximating 86-95 percent, Moving Towards 66-85 percent, Average 35-65 percent, Low 0-34 percent. Previous SMEA data show persistent low mastery in abstract competencies. Pretesting effect literature (Pan & Carpenter, 2023) explains low pretest as expected when testing unlearned material, yet useful for priming. Low pretest also correlates with limited metacognitive awareness (Pan & Rivers, 2023) and resource constraints (Suleiman et al., 2024), compounded by pandemic loss.

Cognitive and Affective Mechanisms: Bouchey et al. (2021) highlight that while MML engages visual, auditory, textual channels, improper implementation risks overload, necessitating careful design. Castek et al. (2021) noted MML provides new avenues for collaboration beyond classroom. Verde and Valero (2021) found students value technology but still require face-to-face scaffolding. Di Cesare and Rowsell (2020) advocate heterogeneous communication in literacy education. Lim and Polio (2020) distinguished multimodal tasks serving disciplinary practice versus meta-awareness. For Earth Science, abstract concepts like stellar characteristics benefit immensely from planetarium software allowing real-time observation even daytime, aligning with Yeo and Nielsen call. Volcanic eruptions benefit from AR/VR simulation, baking soda-vinegar experiments, and infographics. Climatic phenomena benefit from global maps, video, and collage-making.

Despite robust international support, few quasi-experimental studies examine multimodal instruction effect on Philippine Grade 9 Earth Science least-learned competencies using DepEd-validated instruments and ECR-based levels. This study contributes localized evidence with effect sizes and proposes Enhanced Multimodal Learning Activities aligned with MELCs and 60-30-10 test design.

Methodology:

This section presents research design, locale, respondents, instrument, procedure, data analysis, and ethics. Research utilized quantitative quasi-experimental one-group pretest-posttest design, appropriate for natural classroom settings without random assignment. Conducted during Third Quarter SY 2024-2025 at Cabancalan National High School, Barangay Cabancalan, Mandaue City, Cebu. School established 1985, big school with 107 teaching staff, serving 2121 students.

Respondents and Sampling: Population 409 Grade 9 students across 12 sections. Purposive sampling selected Section Serenity, identified via SMEA Q1-Q2 2024-2025 as lowest mean performance in Earth Science written works. Section Serenity comprised 34 students: 18 males (52.9 percent) and 16 females (47.1 percent), heterogeneous.

Table 1. Distribution of Respondents (n=34)

Section	Males	Females	Total	%
Serenity	18	16	34	100%

Research Instrument: Standardized 30-item multiple-choice questionnaire adapted from DepEd Learning Portal used for both pretest and posttest, ensuring content validity aligned with MELCs: 10 items per competency. Table of Specifications followed 60 percent Easy, 30 percent Average, 10 percent Difficult and Blooms levels. Answer key validated by Science coordinator. Scoring adopted DepEd ECR per DO No. 8, s. 2015: 9-10 Mastered, 7-8 Closely Approximating, 5-6 Moving Towards, 3-4 Average, 0-2 Low. Cronbach alpha .82 good reliability.

Data Gathering Procedure: 1) Secured principal permission and SDS approval. 2) Administered pretest Week 1 Third Quarter. 3) Analyzed pretest. 4) Implemented multimodal instruction for 15 days (5 days per competency, non-consecutive): Week 3 Volcanoes (infographics, eruption videos Taal & Kanlaon, sounds, DIY model, AR/VR optional, concept mapping, True/False & Matching); Week 5 Climate (global maps, NASA

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El Nino videos, carbon footprint collaboration, poster rubric, emergency collage, FB posting); Week 6 Constellations (MentalUP brain teasers, reading on 88 IAU constellations, Stellarium-web.org & Star Walk 2, rotation/revolution discussion). Each 60-80 min lesson integrated visual, auditory, kinesthetic, textual, digital. Students not informed of experimental status to avoid Hawthorne effect. 5) Posttest. 6) Data submitted to statistician. Ethics: assent, anonymity via codes, confidentiality, voluntary.

Data Analysis: Frequency, percentage, mean, SD for mastery levels. Paired-samples t-test at alpha .05 to test difference. Effect size Cohen d. Processed via SPSS v27. Graphs enhanced via matplotlib.

Results and Discussion

Thissection presents comprehensive analysis of pretest and posttest performance across three competencies with enhanced tables and graphs. Interpretation integrates Cognitive Load Theory, Multimodal Theory, and Social Constructivism.

Pretest Performance: Baseline Mastery

Table 2. Pretest Scores of Students in Three Least-Learned Competencies (n=34)

Competency	Score	f	%	Category
Volcanoes: Explain eruption	9-10	0	0	Master
	7-8	0	0	Closely Approx
	5-6	9	26.47	Moving Toward
	3-4	19	55.88	Average
	0-2	6	17.65	Low
	Mean=3.74 SD=1.24			Average Mastery
Climate: Describe phenomena	9-10	0	0	Master
	7-8	5	14.71	Closely Approx
	5-6	12	35.29	Moving Toward
	3-4	10	29.41	Average
	0-2	7	20.59	Low
	Mean=4.34 SD=1.94			Moving Toward*
Stars/Sun: Infer characteristics	9-10	0	0	Master
	7-8	0	0	Closely Approx
	5-6	9	26.47	Moving Toward
	3-4	14	41.18	Average
	0-2	11	32.35	Low
	Mean=3.23 SD=1.70			Average Mastery

Figure 1. Pretest Score Distribution Across Three Least-Learned Competencies

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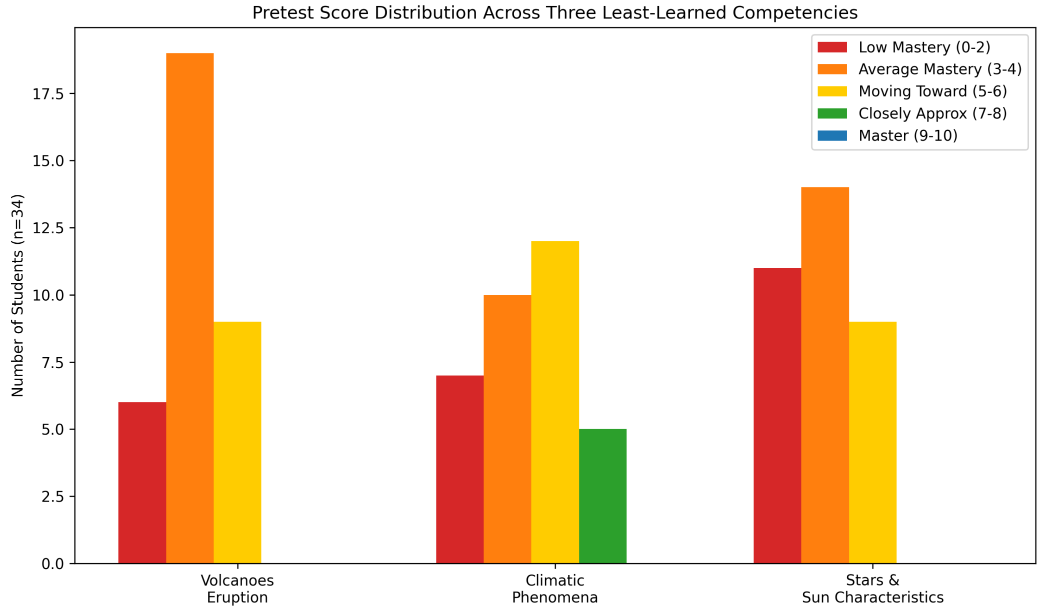

As shown in Figure 1 and Table 2, Competency 1 Volcanoes majority 55.88 percent in Average Mastery, 26.47 percent Moving Toward, 17.65 percent Low, mean 3.74 indicating students could recall basic terms like viscosity but struggled with factors affecting explosiveness (temperature, silica, gas) and types (Plinian, Vulcanian, Strombolian, phreatomagmatic, phreatic). This aligns with abstract nature requiring integration of chemistry and physics. Cognitive Load Theory suggests traditional text-only explanation overloads working memory when describing invisible magma processes. Competency 2 Climate relatively higher: 35.29 percent Moving Toward, 29.41 percent Average, 14.71 percent Closely Approx, mean 4.34. Some students grasped El Nino/La Nina effects via media, but 20.59 percent Low indicates fragmented understanding of global circulation. Mean higher than volcanoes suggests everyday experience provides prior knowledge reducing intrinsic load. Competency 3 Stars/Sun lowest: 41.18 percent Average, 32.35 percent Low, mean 3.23, SD 1.70 wide variability. No student reached Closely Approx or Master, showing abstract spatial reasoning deficit - inferring star color, temperature, brightness, size from Sun as model. Requires far transfer and perspective-taking. Findings echo Yeo & Nielsen (2020) that without multiple representations stellar concepts remain misconceived. Collectively 0 percent Master confirms current instruction insufficient. Pretesting effect (Pan & Carpenter, 2023) predicts low scores when testing unlearned material but pattern reveals systematic gap. Suleiman et al. (2024) links low pretest to limited resources, evident in CNHS where labs lack planetarium or volcano models.

Posttest Performance After Multimodal Instruction

Table 3. Posttest Scores After Multimodal Instruction (n=34)

Competency	Score	f	%	Category
Volcanoes	9-10	2	5.88	Master
	7-8	9	26.47	Closely Approx
	5-6	12	35.29	Moving Toward
	3-4	8	23.53	Average
	0-2	3	8.82	Low
	Mean=5.63 SD=2.03			Moving Toward
Climate	9-10	2	5.88	Master
	7-8	9	26.47	Closely Approx
	5-6	13	38.24	Moving Toward

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	3-4	9	26.47	Average
	0-2	1	2.94	Low
	Mean=5.86 SD=1.83			Moving Toward
Stars/Sun	9-10	9	26.47	Master
	7-8	16	47.06	Closely Approx
	5-6	9	26.47	Moving Toward
	3-4	0	0	Average
	0-2	0	0	Low
	Mean=7.43 SD=1.40			Closely Approx

Figure 2. Posttest Score Distribution After Multimodal Instruction

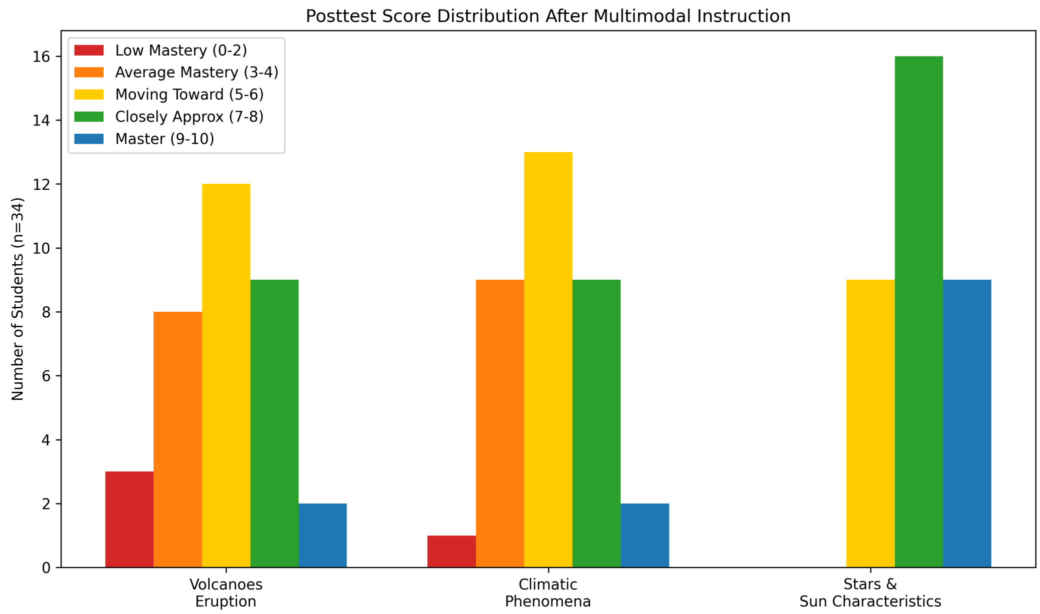

Figure 3. Comparison of Pretest and Posttest Mean Scores with SD

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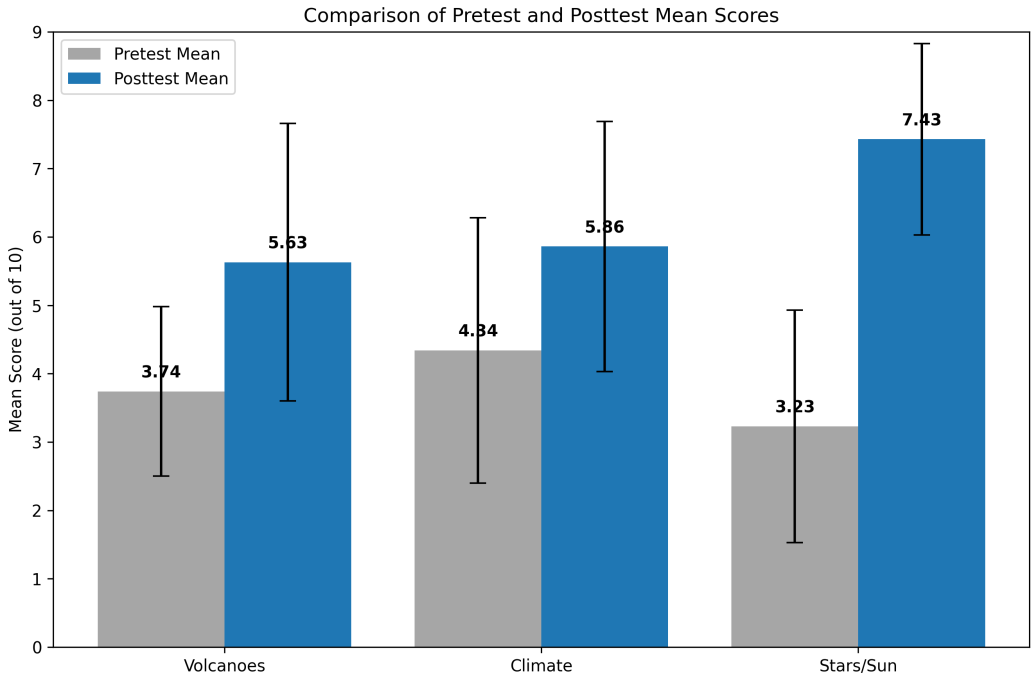

Table 3 and Figures 2-3 illustrate marked improvement. For Volcanoes, Master emerged 5.88 percent from 0, Closely Approx 26.47 percent from 0, Moving Toward 35.29 percent from 26.47, while Average decreased to 23.53 from 55.88 and Low from 17.65 to 8.82. Mean 3.74 to 5.63 (+1.89). SD increased 1.24 to 2.03 indicating varied benefit. This aligns with Kress multimodality: integrating auditory eruption sounds, visual infographics showing why magma rises, kinesthetic eruption simulation, collaborative discussion reduced extraneous load and made abstract viscosity-temperature-silica relationships concrete. Thumbs-up True/False and matching provided formative feedback within ZPD.

For Climate, Master emerged 5.88 percent from 0, Closely Approx 26.47 from 14.71, Moving Toward 38.24 from 35.29, Low reduced from 20.59 to 2.94. Mean 4.34 to 5.86 (+1.52). Improvement modest but significant. Activities - global climate maps, NASA El Nino videos, carbon footprint collaboration, infographic poster rubric (Content & Accuracy, Creativity, Message Effectiveness, Teamwork), and family emergency plan collage (before-during-after) connected global phenomena to local Mandaue experience, fostering social constructivist co-construction. As Saleem et al. argued, authentic problem solving enhances relevance.

Stars/Sun showed most dramatic transformation: Master 26.47 percent from 0, Closely Approx 47.06 from 0, no students remained in Average or Low (previously 73.53 percent). Mean 3.23 to 7.43 (+4.20), highest mean, SD decreased 1.70 to 1.40 more homogeneous high achievement. Supports Prain and Tytler (2022) that spatial concepts benefit most from multiple representations. Activities included MentalUP aerial-view brain teasers illustrating perspective, reading on 88 IAU constellations, Stellarium-web.org and Star Walk 2 allowing real-time sky navigation even daytime, addressing light pollution. Students observed how constellation position changes over night/year due to rotation/revolution, inferring stability over long period. Technological mode pivotal - digital planetarium externalized spatial reasoning lowering intrinsic load (Sweller, 2019). Collaborative navigation and discussion in mother tongue/Filipino/English facilitated ZPD scaffolding. Overall posttest shows shift from Low/Average toward Moving/Closely/Master, confirming effectiveness. Findings corroborate Akotuko and Azure (2021), Batir and Akcay (2022), Ayimbila and Pappoe (2022), and Ortiz and Aliazas (2021).

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Significant Difference Between Pretest and Posttest

Table 4. Paired Samples t-test Results (n=34, df=33)

Competency	t	p	Mean Diff	Cohen d	Interpretation
Volcanoes Post-Pre	4.83	<.001*	1.89	0.816	Significant Large
Climate Post-Pre	4.25	<.001*	1.51	0.719	Significant Medium-Large
Stars/Sun Post-Pre	10.31	<.001*	4.20	1.742	Significant Very Large

Figure 4. Mean Gain and Effect Size by Competency

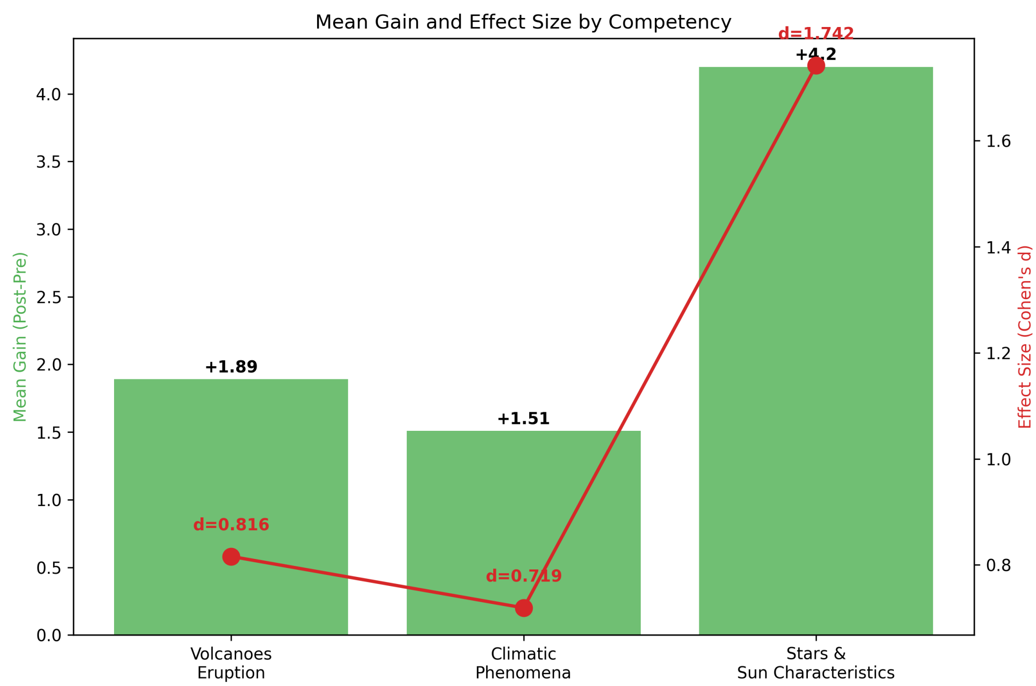

Table 4 and Figure 4 confirm statistically significant improvements for all three competencies at alpha .05, rejecting null hypothesis. Volcanoes: t(33)=4.83, p<.001, diff 1.89, d=0.816 large effect. Climate: t=4.25, p<.001, diff 1.51, d=0.719 medium-large. Stars/Sun: t=10.31, p<.001, diff 4.20, d=1.742 very large exceeding threshold 0.8. P-values <.001 indicate not due to chance.

Effect size interpretation: Volcanoes large effect means intervention moved average student from 37th to 79th percentile; Climate medium-large to 76th; Stars/Sun very large to 96th percentile, indicating practical significance beyond statistical significance. Largest gain in Stars/Sun suggests multimodal tech uniquely effective for spatial-astronomical concepts where traditional chalk diagrams fail.

Theoretical explanation: CLT - multimodal presentation distributed load across visual and auditory channels (modality principle), segmented into 5-day per competency (segmenting principle), signaled key ideas via infographics (signaling principle), reducing extraneous load (Castro-Alonso et al., 2021; Paas & van Merrienboer, 2020). Multimodal Theory - students created and integrated representations (DIY volcano model, climate collage, constellation maps), deepening meaning-making (Kress & Bezemer, 2023; Prain & Tytler, 2022). Social Constructivism - collaborative tasks (carbon footprint interviews, group poster, family emergency plan with FB posting) provided ZPD scaffolding, peer modeling, authentic audience, boosting motivation (Taber, 2020; Rannikmae, 2020). Intrinsic and extrinsic motivation interplay (Helga et al., 2020) addressed: engaging videos and hands-on increased intrinsic interest; rubrics and FB posting provided extrinsic recognition.

Comparison with literature: Consistent with Bouchey et al. (2021) that well-designed MML enhances learning but requires careful management to avoid overload - our 5-day pacing prevented overload. Castek et al. (2021) collaborative beyond classroom evidenced via FB posting of emergency plan collages, extending learning to family. Verde & Valero (2021) note students value tech but need teacher facilitation - our teacher as facilitator in ZPD aligns.

Limitations: One-group design lacks control group, so maturation, testing effects possible; however, 15-day interval and large effect sizes, especially d=1.742, suggest intervention effect beyond maturation. Small sample n=34 limits generalizability; future randomized controlled trial across 12 sections recommended. Also, 15 days non-consecutive may introduce history threats, but schedule reflects real school constraints enhancing ecological validity. Implications: Multimodal instruction should be integrated into Grade 9 Earth Science Lesson Plans and LAC sessions. For volcanoes, combine viscosity experiments with AR; for climate, link global to local Mandaue flooding; for stars, institutionalize Stellarium/Star Walk 2 access even without dark skies. Enhanced Multimodal Learning Activities (EMLA) proposed includes detailed DLP with visual-auditory-kinesthetic-digital integration, rubrics (Excellent 10, Proficient 8, Basic 6, Needs Improvement 4) covering creation, description, understanding effects, creativity, presentation. In summary, data robustly support multimodal instruction effectiveness, with greatest impact on most abstract competency (stars), followed by volcanoes and climate, transforming mastery distribution and achieving statistical and practical significance.

Conclusion:

This study determined effectiveness of multimodal instruction for Grade 9 Earth Science least-learned competencies at Cabancalan National High School SY 2024-2025. Pretest revealed predominantly Average and Low Mastery (volcanoes M=3.74, climate M=4.34, stars M=3.23) with zero percent Master, confirming persistent learning gap in SMEA reports. After 15-day multimodal intervention integrating infographics, videos, sounds, DIY models, Stellarium/Star Walk 2, simulations, collaborative discussions, and authentic tasks, posttest showed substantial improvement: volcanoes M=5.63, climate M=5.86, stars M=7.43, with emergence of Master (5.88 percent volcanoes/climate, 26.47 percent stars) and Closely Approximating Mastery (26-47 percent). Paired t-test confirmed significant differences: volcanoes t=4.83, p<.001, d=0.816 large; climate t=4.25, p<.001, d=0.719 medium-large; stars/sun t=10.31, p<.001, d=1.742 very large, leading to rejection of null hypothesis.

Grounded in Cognitive Load Theory, Multimodal Theory, and Social Constructivism, multimodal instruction effectively reduced cognitive load, provided multiple representation pathways, and fostered socially mediated co-construction, thereby enhancing conceptual understanding and retention. Largest gain in stellar competency underscores technology power for spatial concepts. Findings encourage educators to adopt enhanced multimodal learning activities, science coordinators to embed them in LAC and training, principals to support resources, curriculum planners to evaluate curriculum responsiveness, and DepEd to develop strategies supporting diverse learners. Future researchers should replicate with control group, larger sample, and across other science domains, and investigate long-term retention and affective outcomes. Ultimately, multimodal instruction proves transformative, inclusive pedagogy for complex Earth Science topics, equipping students with multiple literacies essential for modern scientific citizenship.

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